Evaluation of dose calculations on different CBCT-based synthetic-CTs: a comparative sudy

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Purpose/Objective:

Online adaptive radiotherapy (oART) with acquiring cone beam computed tomography (CBCT) is getting more significant and possible with synthetic-CT (sCT) solutions. sCT approach solves some basic critical CBCT problems such as bad image quality, low soft tissue contrast and limited field of view in order to differentiate organs at risk for delineation, to enable full scale dose prediction and re-optimization. In this study, two different sCTs; outsource solution by TheraPanacea (sCT_Thera) that proposes a self-learning GAN based synthetic CT generation and Varian Ethos System based solution (sCT_Ethos) that results of the deformation vector field which is used to generate sCT by deformable image registration of planning CT with CBCT, were tested in the scope of CBCT-based sCT full scale dose calculation.

Material/Methods:

A retrospective cohort of 18 prostate cancer patients oART treated with Ethos were selected. Planning CTs were deformably registered (warped CTs) to the anatomy of the day CBCTs for each patient to account for changes in the patient anatomy. sCT_Thera were generated by using GAN based self-learning and sCT_Ethos were obtained from the Ethos System. Calculated plans on planning CTs of each patient were re-calculated on the warped CT (wCT) and re-calculations were repeated on the both sCTs solutions for dosimetric evaluation. For the analysis, wCTs and sCTs were compared based on a) DVH based parameters (Dmax, Dmean, D98%, D95%, D50%, D5%, D2% for PTV), and b) 2D dose distribution comparison with gamma analysis method with >95% gamma passing rates (GPRs) for 2%/2mm DTA and 3%/3mm DTA with different dose cut-off.

Results:

Table 1 shows comparative results of relative dose differences between the dose generated on the wCT and sCTs. The differences in DVH are represented by the median and mean relative difference with the minimum and the maximum values for the seven DVH indicators: Dmean, Dmax, D98%, D95%, D50%, D5% and D2% of PTV. The highest and lowest median differences were observed for Dmax (3.73% - sCT_Ethos) and D95% (0.22% - sCT_Thera).

Structure	DVH parameter	Median relative dose difference with wCT (%)		Mean relative dose difference with wCT (%)		Minimum relative dose difference with wCT (%)		Maximum relative dose difference with wCT (%)	
		sCT Thera	sCT Ethos	sCT Thera	sCT Ethos	sCT Thera	sCT Ethos	sCT Ther	sCT Ethos
PTV	Dmean	0.23	2.60	0.66	2.90	0.00	1.44	8.81	14.51
	Dmax	0.61	3.73	0.82	3.71	0.04	1.30	2.95	6.89
	D98%	0.36	2.66	0.65	6.49	0.03	1.05	6.95	55.54
	D95%	0.40	2.64	0.44	6.30	0.00	1.06	1.34	53.04
	D50%	0.22	2.71	0.72	3.03	0.00	1.26	10.00	14.64
	D5%	0.31	2.81	0.46	3.10	0.00	1.49	4.13	15.07
	D2%	0.40	3.01	0.48	3.15	0.00	1.21	3.27	12.27

Table 1: Overall dosimetric results comparing synthetic-CTs from sCT_Thera and sCT_Ethos with warped CTs.

The GPRs results obtained on sCT_Thera with 0%, 10% and 20% dose cut off, represented by the median values in table 2, were 99.34%, 98.87% and 99.42% for 2%/2mm and 99.81%, 99.61% and 99.83% for 3%/3mm; GPRs on sCT_Ethos with 0%, 10% and 20% dose cut off were obtained as 98.87%, 97.58% and 97.86% for 2%/2mm and 99.85%, 99.68% and 99.75% for 3%/3mm, respectively.

	2%/2mm (0% threshold)		2%/2mm (10% threshold)		2%/2mm (20% threshold)	
	SCT Thera	sCT Ethos	sCT Thera	sCT Ethos	sCT Thera	sCT Ethos
Median	99.34	98.87	98.87	97.58	99.42	97.86
Minimum	89.23	96.44	94.32	90.75	97.30	88.51
Maximum	99.92	100.00	99.82	100.00	99.86	100.00
	3%/3mm (0% threshold)		3%/3mm (10% threshold)		3%/3mm (20% threshold)	
	SCT Thera	sCT Ethos	sCT Thera	sCT Ethos	sCT Thera	sCT Ethos
Median	99.81	99.85	99.61	99.68	99.83	99.75
Minimum	94.97	99.30	95.96	98.80	98.51	99.06
Maximum	100.00	100.00	99.99	100.00	99.99	100.00

Table 2: Global gamma pass rates with 0%, 10% and 20% dose cut off for 2%/2mm and 3%/3mm

Conclusion:

In this work, we have demonstrated that GAN self-learning synthetic-CT generated from anatomy of day CBCT performs better than Ethos based synthetic-CT when it comes to full-scale dose calculation in the scope of adaptive treatment. Both relative dose difference and global gamma pass rates showed better results for the self-learning GAN solution of sCT_Thera than the current synthetic solution of Ethos system.

Keywords: Adaptive, synthetic-CT from CBCT, Dose calculation